CHAPTER 10
FIRE PROTECTION SYSTEMS

GENERAL

Because fire is one of the most dangerous threats to an aircraft, the potential fire zones of modern multi-engine aircraft are protected by a fixed fire protection system. A "fire zone" is an area or region of an aircraft designed by the manufacturer to require fire detection and/or fire extinguishing equipment and a high degree of inherent fire resistance. The term "fixed" describes a permanently installed system in contrast to any type of portable fire extinguishing equipment, such as a hand-held CO_2 fire extinguisher.

A complete fire protection system on modern aircraft and on many older model aircraft includes both a fire detection and a fire extinguishing system.

To detect fires or overheat conditions, detectors are placed in the various zones to be monitored. Fires are detected in reciprocating engine aircraft, using one or more of the following:

(1) Overheat detectors.
(2) Rate-of-temperature-rise detectors.
(3) Flame detectors.
(4) Observation by crewmembers.

In addition to these methods, other types of detectors are used in aircraft fire protection systems, but are seldom used to detect engine fires; for example, smoke detectors are better suited to monitor areas such as baggage compartments, where materials burn slowly, or smolder. Other types of detectors in this category include carbon monoxide detectors and chemical sampling equipment capable of detecting combustible mixtures that can lead to accumulations of explosive gases.

Detection Methods

The following list of detection methods includes those most commonly used in turbine engine aircraft fire protection systems. The complete aircraft fire protection system of most large turbine engine aircraft will incorporate several of these different detection methods.

(1) Rate-of-temperature-rise detectors.
(2) Radiation sensing detectors.
(3) Smoke detectors.
(4) Overheat detectors.
(5) Carbon monoxide detectors.
(6) Combustible mixture detectors.
(7) Fiber-optic detectors.
(8) Observation of crew or passengers.

The three types of detectors most commonly used for fast detection of fires are the rate-of-rise, radiation sensing, and overheat detectors.

Detection System Requirements

Fire protection systems on modern aircraft do not rely on observation by crewmembers as a primary method of fire detection. An ideal fire detection system will include as many as possible of the following features:

(1) A system which will not cause false warnings under any flight or ground operating conditions.
(2) Rapid indication of a fire and accurate location of the fire.
(3) Accurate indication that a fire is out.
(4) Indication that a fire has re-ignited.
(5) Continuous indication for duration of a fire.
(6) Means for electrically testing the detector system from the aircraft cockpit.
(7) Detectors which resist exposure to oil, water, vibration, extreme temperatures, maintenance handling.
(8) Detectors which are light in weight and easily adaptable to any mounting position.
(9) Detector circuitry which operates directly from the aircraft power system without inverters.
(10) Minimum electrical current requirements when not indicating a fire.
(11) Each detection system should actuate a cockpit light indicating the location of the fire and an audible alarm system.
(12) A separate detection system for each engine.

There are a number of detectors or sensing devices available. Many older model aircraft still operating are equipped with some type of thermal switch system or thermocouple system.

FIRE DETECTION SYSTEMS

A fire detection system should signal the presence of a fire. Units of the system are installed in locations where there are greater possibilities of a fire. Three detector systems in common use are the thermal switch system, thermocouple system, and the continuous-loop detector system.

Thermal Switch System

A thermal switch system consists of one or more lights energized by the aircraft power system and thermal switches that control operation of the light(s). These thermal switches are heat-sensitive units that complete electrical circuits at a certain temperature. They are connected in parallel with each other but in series with the indicator lights (figure 10–1). If the temperature rises above a set value in any one section of the circuit, the thermal switch will close, completing the light circuit to indicate the presence of a fire or overheat condition.

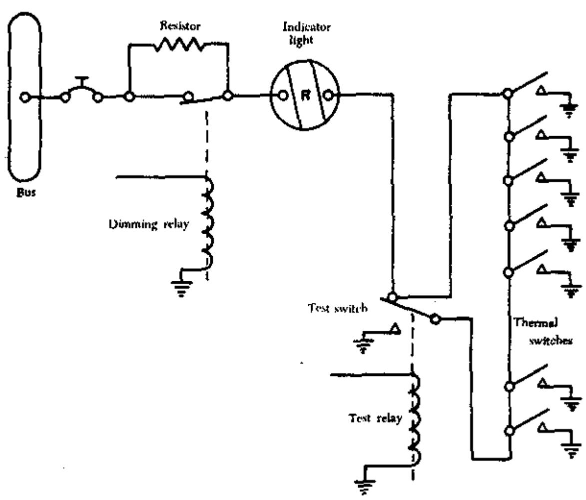

FIGURE 10–1. Thermal switch fire circuit.

No set number of thermal switches is required; the exact number is usually determined by the aircraft manufacturer. On some installations several thermal detectors are connected to one light; on others there may be only one thermal switch for an indicator light.

Some warning lights are the "push-to-test" type. The bulb is tested by pushing it in to complete an auxiliary test circuit. The circuit in figure 10–1 includes a test relay. With the relay contact in the position shown, there are two possible paths for current flow from the switches to the light. This is an additional safety feature. Energizing the test relay completes a series circuit and checks all the wiring and the light bulb.

Also included in the circuit shown in figure 10–1 is a dimming relay. By energizing the dimming relay, the circuit is altered to include a resistor in series with the light. In some installations several circuits are wired through the dimming relay, and all the warning lights may be dimmed at the same time.

The thermal switch system uses a bimetallic thermostat switch or spot detector similar to that shown in figure 10–2. Each detector unit consists of a bimetallic thermoswitch. Most spot detectors are dual-terminal thermoswitches.

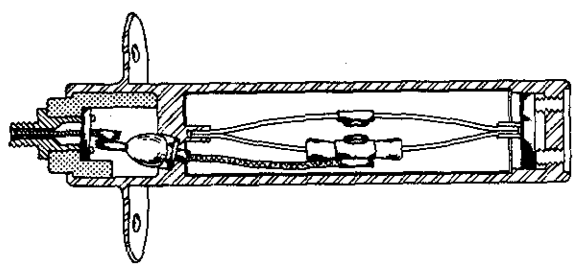

FIGURE 10–2. Fenwal spot detector.

Fenwal Spot Detector

Fenwal spot detectors are wired in parallel between two complete loops of wiring, as illustrated in figure 10–3. Thus, the system can withstand one fault, either an electrical open circuit or a short to ground, without sounding a false fire warning. A double fault must exist before a false fire warning can occur. In case of a fire or overheat condition, the spot-detector switch closes and completes a circuit to sound an alarm.

The Fenwal spot-detector system operates without a control unit. When an overheat condition or a fire causes the switch in a detector to close, the alarm bell sounds and a warning light for the affected area is lighted.

Thermocouple Systems

The thermocouple fire warning system operates on an entirely different principle than the thermal switch system. A thermocouple depends upon the rate of temperature rise and will not give a warning when an engine slowly overheats or a short circuit

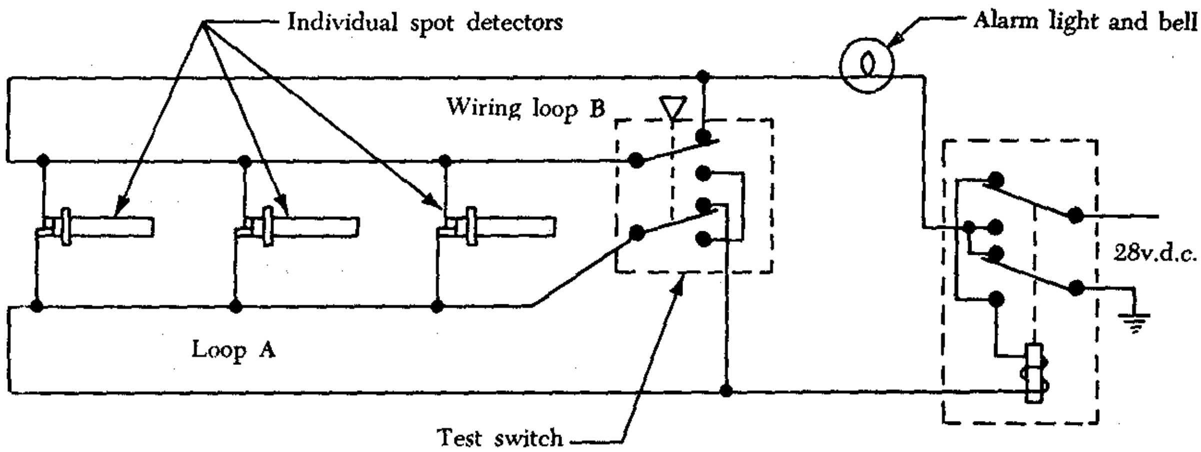

FIGURE 10–3. Fenwal spot-detector circuit.

develops. The system consists of a relay box, warning lights, and thermocouples. The wiring system of these units may be divided into the following circuits (figure 10–4): (1) The detector circuit, (2) the alarm circuit, and (3) the test circuit.

The relay box contains two relays, the sensitive relay and the slave relay, and the thermal test unit. Such a box may contain from one to eight identical circuits, depending on the number of potential fire zones. The relays control the warning lights. In turn, the thermocouples control the operation of the relays. The circuit consists of several thermocouples in series with each other and with the sensitive relay.

The thermocouple is constructed of two dissimilar metals such as chromel and constantan. The point where these metals are joined and will be exposed to the heat of a fire is called a hot junction. There is also a reference junction enclosed in a dead air space between two insulation blocks. A metal cage surrounds the thermocouple to give mechanical protection without hindering the free movement of air to the hot junction.

If the temperature rises rapidly, the thermocouple produces a voltage because of the temperature difference between the reference junction and the hot junction. If both junctions are heated at the same rate, no voltage will result and no warning signal is given.

If there is a fire, however, the hot junction will heat more rapidly than the reference junction. The ensuing voltage causes a current to flow within the detector circuit. Any time the current is greater than 4 milliamperes (0.004 ampere), the sensitive relay will close. This will complete a circuit from

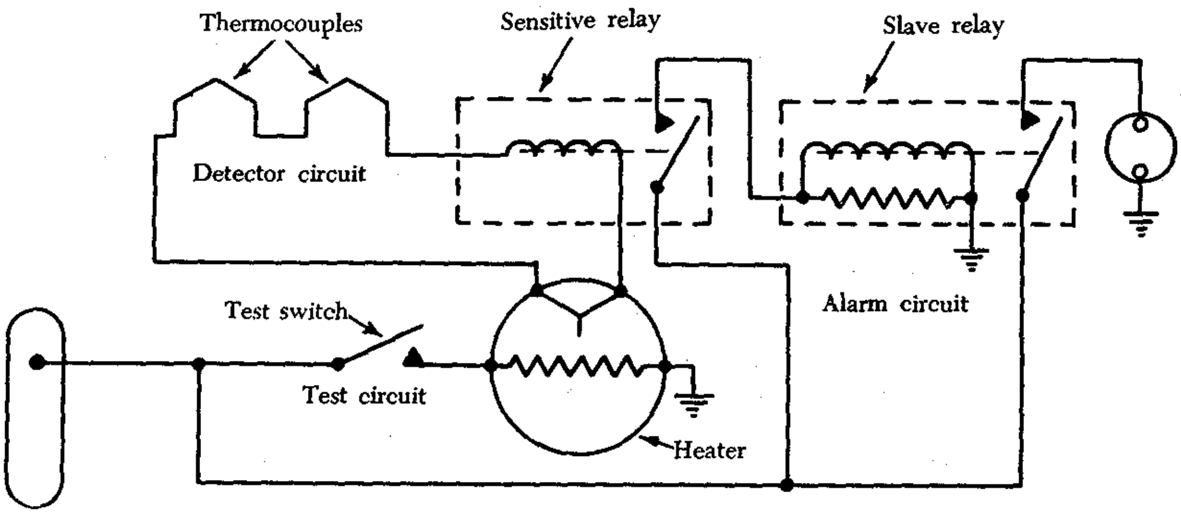

FIGURE 10–4. Thermocouple fire warning circuit.

the aircraft power system to the coil of the slave relay which closes and completes the circuit to the fire-warning light.

The total number of thermocouples used in individual detector circuits depends on the size of the fire zone and the total circuit resistance. The total resistance usually does not exceed 5 ohms. As shown in figure 10–4, the circuit has two resistors. The resistor connected across the terminals of the slave relay absorbs the coil's self-induced voltage. This is to prevent arcing across the points of the sensitive relay, since the contacts of the sensitive relay are so fragile they would burn or weld if arcing were permitted.

When the sensitive relay opens, the circuit to the slave relay is interrupted and the magnetic field around its coil collapses. When this happens, the coil gets a voltage through self-induction, but with the resistor across the coil terminals, there is a path for any current flow as a result of this voltage. Thus, arcing at the sensitive relay contacts is eliminated.

Continuous-Loop Detector Systems

A continuous-loop detector or sensing system permits more complete coverage of a fire hazard area than any type of spot-type temperature detectors. Continuous-loop systems are versions of the thermal switch system. They are overheat systems, heat-sensitive units that complete electrical circuits at a certain temperature. There is no rate-of-heat-rise sensitivity in a continuous-loop system. Two widely used types of continuous-loop systems are the Kidde and the Fenwal systems.

In the Kidde continuous-loop system (figure 10–5), two wires are imbedded in a special ceramic core within an Inconel tube.

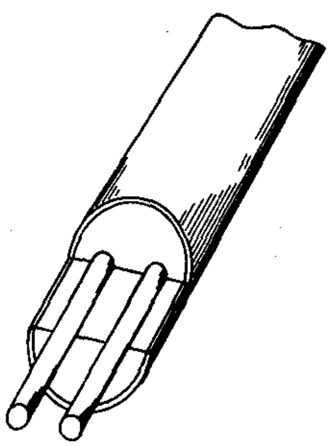

FIGURE 10–5. Kidde sensing element.

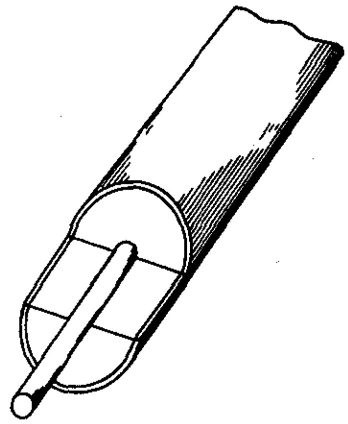

FIGURE 10–6. Fenwal sensing element.

One of the two wires in the Kidde sensing system is welded to the case at each end and acts as an internal ground. The second wire is a hot lead (above ground potential) that provides a current signal when the ceramic core material changes its resistance with a change in temperature.

Another continuous-loop system, the Fenwal system (figure 10–6), uses a single wire surrounded by a continuous string of ceramic beads in an Inconel tube.

The beads in the Fenwal detector are wetted with a eutectic salt which possesses the characteristic of suddenly lowering its electrical resistance as the sensing element reaches its alarm temperature. In both the Kidde and the Fenwal systems, the resistance of the ceramic or eutectic salt core material prevents electrical current from flowing at normal temperatures. In case of a fire or overheat condition, the core resistance drops and current flows between the signal wire and ground, energizing the alarm system.

The Kidde sensing elements are connected to a relay control unit. This unit constantly measures the total resistance of the full sensing loop. The system senses the average temperature, as well as any single hot spot.

The Fenwal system uses a magnetic amplifier control unit. This system is non-averaging but will sound an alarm when any portion of its sensing element reaches the alarm temperature.

Both systems continuously monitor temperatures in the affected compartments, and both will automatically reset following a fire or overheat alarm after the overheat condition is removed or the fire extinguished.

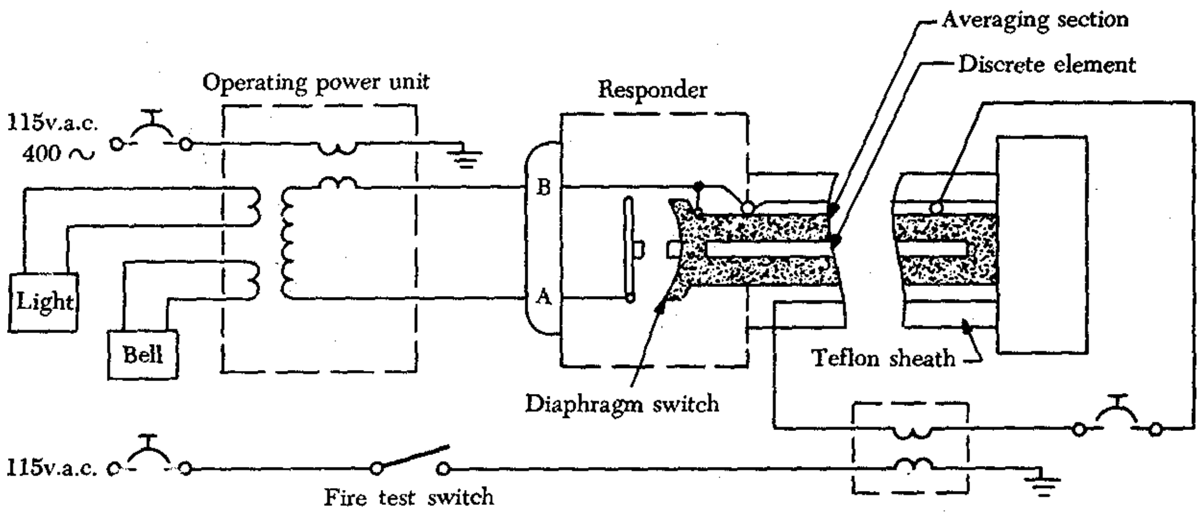

FIGURE 10–7. Lindberg fire detection system schematic.

Continuous Element System

The Lindberg fire detection system (figure 10–7) is a continuous-element type detector consisting of a stainless steel tube containing a discrete element. This element has been processed to absorb gas in proportion to the operating temperature set point. When the temperature rises (due to a fire or overheat condition) to the operating temperature set point, the heat generated causes the gas to be released from the element. Release of the gas causes the pressure in the stainless steel tube to increase. This pressure rise mechanically actuates the diaphragm switch in the responder unit, activating the warning lights and an alarm bell.

A fire test switch is used to heat the sensors, expanding the trapped gas. The pressure generated closes the diaphragm switch, activating the warning system.

Overheat Warning Systems

Overheat warning systems are used on some aircraft to indicate high area temperatures that may lead to a fire. The number of overheat warning systems varies with the aircraft. On some aircraft, they are provided for each engine turbine and each nacelle, on others they are provided for wheel well areas and for the pneumatic manifold.

When an overheat condition occurs in the detector area, the system causes a light on the fire control panels to flash.

In most systems the detector is a type of thermal switch. Each detector is operated when the heat rises to a specified temperature. This temperature depends upon the system and the type and model of the aircraft. The switch contacts of the detector are on spring struts, which close whenever the meter case is expanded by heat. One contact of each detector is grounded through the detector mounting bracket. The other contacts of all detectors connect in parallel to the closed loop of the warning light circuit. Thus, the closed contacts of any one detector can cause the warning lights to burn.

When the detector contacts close, a ground is provided for the warning light circuit. Current then flows from an electrical bus through the warning lights and a flasher or keyer to ground. Because of the flasher in the circuit, the lights flash on and off to indicate an overheat condition.

TYPES OF FIRES

The National Fire Protection Association has classified fires in three basic types:

a. Class A fires, defined as fires in ordinary combustible materials such as wood, cloth, paper, upholstery materials, etc.

b. Class B fires, defined as fires in flammable petroleum products or other flammable or combustible liquids, greases, solvents, paints, etc.

c. Class C fires, defined as fires involving energized electrical equipment where the electrical non-conductivity of the extinguishing media is of importance. In most cases where electrical equipment is de-energized, extinguishers suitable for use on Class A or B fires may be employed effectively.

Aircraft fires, in flight or on the ground, may encompass either or all of these type fires. Therefore, detection systems, extinguishing systems and extinguishing agents as applied to each type fire must be considered. Each type fire has characteristics that require special handling. Agents usable on Class A fires are not acceptable on Class B or C fires. Agents effective on Class B or C fires will have some effect on Class A fires but are not the most efficient.

FIRE ZONE CLASSIFICATION

Powerplant compartments are classified into zones based on the air flow through them.

a. *Class A Zone.* Zones having large quantities of air flowing past regular arrangements of similarly shaped obstructions. The power section of a reciprocating engine is usually of this type.

b. *Class B Zone.* Zones having large quantities of air flowing past aerodynamically clean obstructions. Heat exchanger ducts and exhaust manifold shrouds are usually of this type. Also, zones where the inside of the enclosing cowling or other closure is smooth, free of pockets, and adequately drained so leaking flammables cannot puddle are of this type. Turbine engine compartments may be considered in this class if engine surfaces are aerodynamically clean and all airframe structural formers are covered by a fireproof liner to produce an aerodynamically clean enclosure surface.

c. *Class C Zone.* Zones having relatively small air flow. An engine accessory compartment separated from the power section is an example of this type of zone.

d. *Class D Zone.* Zones having very little or no air flow. These include wing compartments and wheel wells where little ventilation is provided.

e. *Class X Zone.* Zones having large quantities of air flowing through them and are of unusual construction making uniform distribution of the extinguishing agent very difficult. Zones containing deeply recessed spaces and pockets between large structural formers are of this type. Tests indicate agent requirements to be double those for Class A zones.

EXTINGUISHING AGENT CHARACTERISTICS

Aircraft fire extinguishing agents have some common characteristics which make them compatible to aircraft fire extinguishing systems. All agents may be stored for long time periods without adversely affecting the system components or agent quality. Agents in current use will not freeze at normally expected atmospheric temperatures. The nature of the devices inside a powerplant compartment require agents that are not only useful against flammable fluid fires but also effective on electrically caused fires. The various agents' characteristics are narratively described and then summarized in tabular form in Figures 10–8, 10–9, and 10–10. Agents are classified into two general categories based on the mechanics of extinguishing action: the halogenated hydrocarbon agents and the inert cold gas agents.

a. The Halogenated Hydrocarbon Agents.

(1) The most effective agents are the compounds formed by replacement of one or more of the hydrogen atoms in the simple hydrocarbons methane and ethane by halogen atoms.

(a) The halogens used to form extinguishing compounds are fluorine, chlorine, and bromine. Iodine may be used but is more expensive with no compensating advantage. The extinguishing compounds are made up of the element carbon in all cases, along with different combinations of hydrogen, fluorine, chlorine, and bromine. Completely halogenated agents contain no hydrogen atoms in the compound, are thus more stable in the heat associated with fire, and are considered safer. Incompletely halogenated compounds, those with one or more hydrogen atoms, are classed as fire extinguishing agents but under certain conditions may become flammable.

(b) The probable extinguishing mechanism of halogenated agents is a "chemical interference" in the combustion process between fuel and oxidizer. Experimental evidence indicates that the most likely method of transferring energy in the combustion process is by "molecule fragments" resulting from the chemical reaction of the constituents. If these fragments are blocked from transferring their energy to the unburned fuel molecules the combustion process may be slowed or stopped completely (extinguished). It is believed that the halogenated agents react with the molecular fragments, thus preventing the energy transfer. This may be termed "chemical cooling" or "energy transfer blocking." This extinguishing mechanism is much more effective than oxygen dilution and cooling.

AGENT	ADVANTAGES	DISADVANTAGES
Bromotrifluoromethane CBr_3F "BT" Halon 1301	Excellent extinguishant, about 4x as effective as "CB" Nontoxic at normal temperatures Noncorrosive Compatible with conventional system, excellent with HRD	Moderately high cost Heavier storage containers required
Bromochlorodi-fluoromethane $CBrClF_2$ "BCF" Halon 1211	Very effective extinguishant Lightweight storage containers	Low relative toxicity Requires N_2 pressure for expellant
Bromochloromethane CH_2BrCl "CB" Halon 1011	Very effective extinguishant when used in conventional systems Noncorrosive to steel and brass Lightweight storage containers	Relatively toxic at normal temperatures Very toxic when pyrolized Requires mechanical vaporization during discharge Corrosive to aluminum and magnesium
Methyl bromide CH_3Br "MB" Halon 1001	More effective than CO_2 Lightweight storage containers Readily available Low cost Compatible with conventional and HRD systems	Relatively toxic Rapidly corrodes aluminum, zinc, and magnesium
Carbon tetrachloride CCl_4 "CTC" Halon 104	Liquid at normal temperatures Readily available Low cost	Relatively toxic Severely toxic when pyrolized Corrosive to iron and other metals Requires propellant charge
Dibromodifluoromethane CBr_2F_2 Halon 1202	Very effective extinguishant Noncorrosive to aluminum, steel and brass Lightweight storage containers Conventional or HRD system	Relatively toxic at normal temperatures Very toxic when pyrolized High cost.
Carbon dioxide CO_2	Conventional or HRD system Relatively nontoxic Noncorrosive Readily available Low cost Under normal temperatures it provides its own propellant	Can cause suffocation of personnel from lengthy exposure Requires heavy storage containers Requires N_2 booster in cold climates
Nitrogen N_2	Very effective extinguishant Noncorrosive Basically nontoxic System may provide large quantities of extinguishant N_2 provides greatest O_2 dilution	Can cause suffocation from lengthly exposure Requires dewar to maintain liquid

FIGURE 10-8. Extinguishing Agent Comparison.

(c) Since halogenated agents react with the molecular fragments, new compounds are formed which in some cases present hazards much greater than the agents themselves. Carbon tetrachloride, for example, may form phosgene, used in warfare as a poison gas. However, most agents generate relatively harmless halogen acids. This chemical reaction caused by heat (pyrolysis) makes some of these agents quite toxic in extinguishing use while being essentially nontoxic under normal room conditions. To evaluate the relative toxic hazard for

GROUP	DEFINITION	EXAMPLES
1 (Highest)	Gases or vapors which in concentration of the order of 1/2 to 1 per cent by volume for duration of exposure of the order of 5 minutes are lethal or produce serious injury.	Sulfur dioxide
2	Gases or vapors which in concentrations of the order of 1/2 to 1 per cent by volume for durations of exposure of the order of 1/2 hour are lethal or produce serious injury.	Ammonia Methyl bromide
3	Gases or vapors which in concentrations of the order of 2 to 2½ per cent by volume for durations of exposure of the order of 1 hour are lethal or produce serious injury.	Carbon tetrachloride Chloroform
4	Gases or vapors which in concentrations of the order of 2 to 2½ per cent by volume for durations of exposure of the order of 2 hours are lethal or produce serious injury.	Methyl chloride Ethyl bromide
5	Gases or vapors less toxic than Group 4 but more toxic than Group 6.	Methylene chloride Carbon dioxide Ethane, Propane, Butane
6 (Lowest)	Gases or vapors which in concentrations up to at least about 20 per cent by volume for durations of exposure of the order of 2 hours do not produce injury.	Bromotrifluoromethane

FIGURE 10-9. Comparative life hazard of various refrigerants and other vaporizing liquids and gases. (Classified by the Underwriters' Laboratories, Inc.).

each agent, some consideration must be given to the effectiveness of the individual agent. The more effective the agent, the less quantity of agent required and the quicker will be the extinguishment, with less generation of decomposition products.

(d) These agents are classified through a system of "halon numbers" which describes the several chemical compounds making up this family of agents. The first digit represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; and the fifth digit, the number of iodine atoms, if any. Terminal zeroes are not expressed. For example, bromotrifluoromethane ($CBrF_3$), is referred to as Halon 1301.

(e) At ordinary room temperatures some agents are liquids that will vaporize readily though not instantaneously, and are referred to as "vaporizing liquid" extinguishing agents. Other agents are gaseous at normal room temperature but may be liquefied by compression and cooling, enabling them to be stored under pressure as liquids; these are called "liquefied gas" extinguishing agents. Both types of agents may be expelled from extinguishing system storage vessels by using nitrogen gas as a propellant.

(2) Characteristics of some halogenated agents follow:

(a) Bromotrifluoromethane, $CBrF_3$, was developed by the research laboratories of of E. I. DuPont de Nemours & Co. in a program sponsored by the U.S. Armed Forces for the development of an aircraft fire extinguishing agent. It is very effective as an extinguishant, is relatively non-toxic and requires no pressurizing agent. This recently developed agent is gaining in usage because of its obvious advantages.

(b) Bromochlorodifluoromethane, $CBrClF_2$, another very effective agent that has been extensively tested by the U.S. Air Force. It has relatively low toxicity but it requires pressurization by nitrogen to expel it from storage at a satisfactory rate for extinguishment.

(c) Chlorobromomethane, CH_2BrCl, was originally developed in Germany in World War II for military aircraft. It is a more effective extinguishing agent than carbon tetrachloride and is somewhat less toxic although it is classed in the same hazard group.

(d) Methyl bromide, CH_3Br, has been used in the extinguishing systems in British-built aircraft engine installations for many years. Its natural vapor is more toxic than carbon tetrachloride and this characteristic hinders its use. Methyl bromide, as an incompletely halogenated compound with three hydrogen atoms per molecule, is a "borderline" material which may be flammable in itself at elevated temperatures. Tests indicate, however, that it is quite effective in its flame quenching power. Under the conditions found in an aircraft engine nacelle, the explosion suppression characteristic is dominant.

(e) Dibromodifluoromethane, CBr_2F_2 is generally considered more effective than methyl bromide and at least twice as effective as carbon tetrachloride as a flame suppressant. However, its relative toxicity limits its use where it may enter inhabited compartments.

(f) Carbon tetrachloride, CCl_4, is described in this manual primarily because of its historical interest and to provide a comparison with the other agents. CCl_4 is seldom used in aircraft extinguishing systems. It was the first generally accepted agent of the halogenated family and has been used commercially during the past 60 years, particularly for electrical hazards. In recent years, however, use of CCl_4 has declined due principally to the development of more effective agents and in part to the growing concern about the toxic nature of the CCl_4 vapors, especially when decomposed by heat.

b. Inert Cold Gas Agents.

Both carbon dioxide (CO_2) and nitrogen (N_2) are effective extinguishing agents. Both are readily available in gaseous and liquid forms; their main difference is in the temperatures and pressures required to store them in their compact liquid phase.

(1) Carbon dioxide, CO_2, has been used for many years to extinguish flammable fluid fires and fires involving electrical equipment. It is noncombustible and does not react with most substances. It provides its own pressure for discharge from the storage vessel except in extremely cold climates where a booster charge of nitrogen may be added to "winterize" the system. Normally, CO_2 is a gas, but it is easily liquefied by compression and cooling. After liquefication, CO_2 will remain in a closed container as both liquid and gas. When CO_2 is then discharged to the atmosphere, most of the liquid expands to gas. Heat absorbed by the gas during vaporization cools the remaining liquid to $-110°$ F. and it becomes a finely divided white solid, dry ice "snow."

CO_2 is about $1\frac{1}{2}$ times as heavy as air which gives it the ability to replace air above burning surfaces and maintain a smothering atmosphere. CO_2 is effective as an extinguishant primarily because it dilutes the air and reduces the oxygen content so that the air will no longer support combustion. Under certain conditions some cooling effect is also realized. CO_2 is considered only mildly toxic, but it can cause unconsciousness and death by suffocation if the victim is allowed to breath CO_2 in fire extinguishing concentrations for 20 to 30 minutes.

CO_2 is not effective as an extinguishant on fires involving chemicals containing their own oxygen supply, such as cellulose nitrate (some aircraft paints). Also fires involving magnesium and titanium (used in aircraft structures and assemblies) cannot be extinguished by CO_2.

(2) Nitrogen, N_2, is an even more effective extinguishing agent. Like CO_2, N_2 is an inert gas of low toxicity. N_2 extinguishes by oxygen dilution and smothering. It is hazardous to humans in the same way as CO_2. But more cooling is provided by N_2 and pound for pound, N_2 provides almost twice the volume of inert gas to the fire as CO_2 resulting in greater dilution of oxygen.

The main disadvantage of N_2 is that it must be stored as a cyrogenic liquid which requires a dewar and associated plumbing to maintain the $-320°$ F. temperature of liquid nitrogen (LN_2). Some large Air Force aircraft already in service use LN_2 in several ways. LN_2 systems are primarily utilized to inert the

AGENT	SYMBOL	CHEMICAL FORMULA	TYPE OF AGENT	HALON NUMBER	UL TOXICITY GROUPING (3)	SPECIFIC GRAVITY OF LIQUID @ 68°F	SPECIFIC WEIGHT lb./in.³	BOILING POINT, °F	FREEZING POINT, °F	HEAT OF VAPORIZATION (BTU/lb.)	APPROX. LETHAL CON ppm (4)	Vapor Pressure, psi	
												@ 70°F	@ 160°F
Carbon dioxide	CO_2	CO_2	Gas Liquid	—	5	1.529 (1)	0.1234 (2)	−110	−110	112.5	658,000 658,000	750	
Carbon tetrachloride	CTC	CCl_4	Liquid	104	3	1.60	0.059	170	−8	83.5	28,000 300	1.9	12.5
Methyl bromide	MB	CH_3Br	Liquid	1001	2	1.73	0.0625	39	−139	108.2	5,900 9,600	27	120
Bromochloromethane	CB BCM, CMB	CH_2BrCl	Liquid	1011	3	1.94	0.069/ 0.070	149	−124	99.8	65,000 4,000	2.7	17.0
Bromochlorodifluoromethane	BCF	$CBrClF_2$	Liquefied Gas	1211	5	1.83	0.0663	25	−257	57.6	324,000 7,650	35	135
Dibromodifluoromethane		CBr_2F_2	Liquid	1202	4	2.28	0.0822	76	−112	52.4	54,000 1,850	13	58
Bromotrifluoromethane (Bromotri)	BT	$CBrF_3$	Liquefied Gas	1301	6	1.57	0.057	−72	−270.4	47.7	800,000 20,000	212	550
Nitrogen	N_2	N_2	—	—	5	0.97 (1)	0.078 (2)	−320		85			

(1) Dry gas compared to dry air at same temperature and pressure.
(2) Specific weight, lb/ft³ @ 1 atmosphere pressure and 0°C.
(3) See Figure 10-9 for definitions.
(4) 1st value represents unheated agent.
2nd value represents agent heated to 1475°F.

FIGURE 10-10. Characteristics of extinguishing agents.

atmosphere in the fuel tank ullage by replacing most of the air with dry gaseous nitrogen, thereby diluting the oxygen content. With the large quantities of LN_2 thus available, N_2 is also being used for aircraft fire control and is feasible as a practical powerplant fire extinguishing agent.

A long-duration LN_2 system discharge can provide greater safety than conventional short-duration system by cooling potential reignition sources and reducing the vaporization rate of any flammable fluids remaining after extinguishment. Liquid nitrogen systems are expected to see commercial usage in the near future.

FIRE EXTINGUISHING SYSTEMS

a. *High-Rate-of-Discharge Systems.* This term, abbreviated HRD, is applied to the highly effective systems most currently in use. Such HRD systems provide high discharge rates through high pressurization, short feed lines, large discharge valves and outlets. The extinguishing agent is usually one of the halogenated hydrocarbons (halons) sometimes boosted by high-pressure dry nitrogen (N_2). Because the agent and pressurizing gas of an HRD system are released into the zone in one second or less, the zone is temporarily pressurized, and interrupts the ventilating air flow. The few, large sized outlets are carefully located to produce high velocity swirl effects for best distribution.

b. *Conventional Systems.* This term is applied to those fire extinguishing installations first used in aircraft. Still used in some older aircraft, the systems are satisfactory for their intended use but are not as efficient as newer designs. Typically these systems utilize the perforated ring and the so-called distributor-nozzle discharge arrangement. One application is that of a perforated ring in the accessory section of a reciprocating engine where the air flow is low and distribution requirements are not severe. The distributor-nozzle arrangements are used in the power section of reciprocating engine installations with nozzles placed behind each cylinder and in other areas necessary to provide adequate distribution. This system usually uses carbon dioxide (CO_2) for extinguishant but may use any other adequate agent.

RECIPROCATING ENGINE CONVENTIONAL CO_2 SYSTEM

CO_2 is one of the earliest types of fire extinguisher systems for transport aircraft and is still used on many older aircraft.

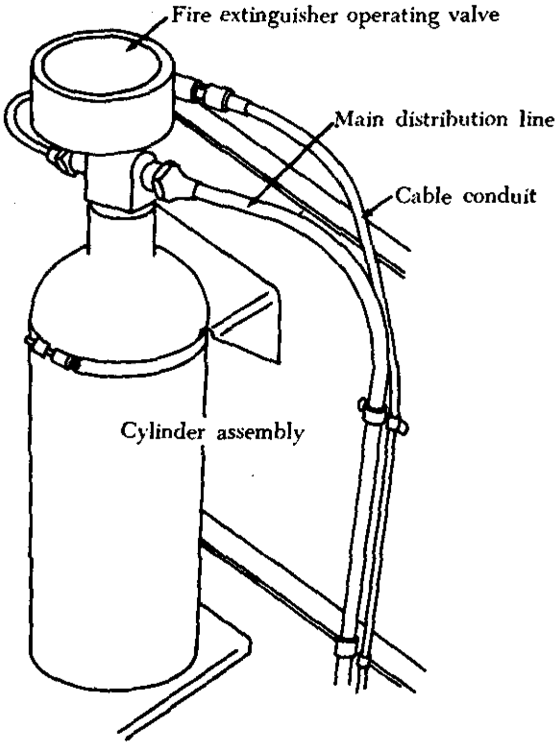

FIGURE 10–11. Carbon dioxide (CO_2) cylinder installation.

This fire extinguisher system is designed around a cylinder (figure 10–11) that stores the flame-smothering CO_2 under pressure and a remote control valve assembly in the cockpit to distribute the extinguishing agent to the engines. The gas is distributed through tubing from the CO_2 cylinder valve to the control valve assembly in the cockpit, and then to the engines via tubing installed in the fuselage and wing tunnels. The tubing terminates in perforated loops which encircle the engines (figure 10–12).

To operate this type of engine fire extinguisher system, the selector valve must be set for the engine which is on fire. An upward pull on the T-shaped control handle located adjacent to the engine selector valve actuates the release lever in the CO_2 cylinder valve. The compressed liquid in the CO_2 cylinder flows in one rapid burst to the outlets in the distribution line (figure 10–12) of the affected engine. Contact with the air converts the liquid into gas and "snow" which smothers the flame.

A more sophisticated type of CO_2 fire protection system is used on many four-engine aircraft. This system is capable of delivering CO_2 twice to any one of the four engines. Fire warning systems are installed at all fire hazardous locations of the aircraft to provide an alarm in case of fire.

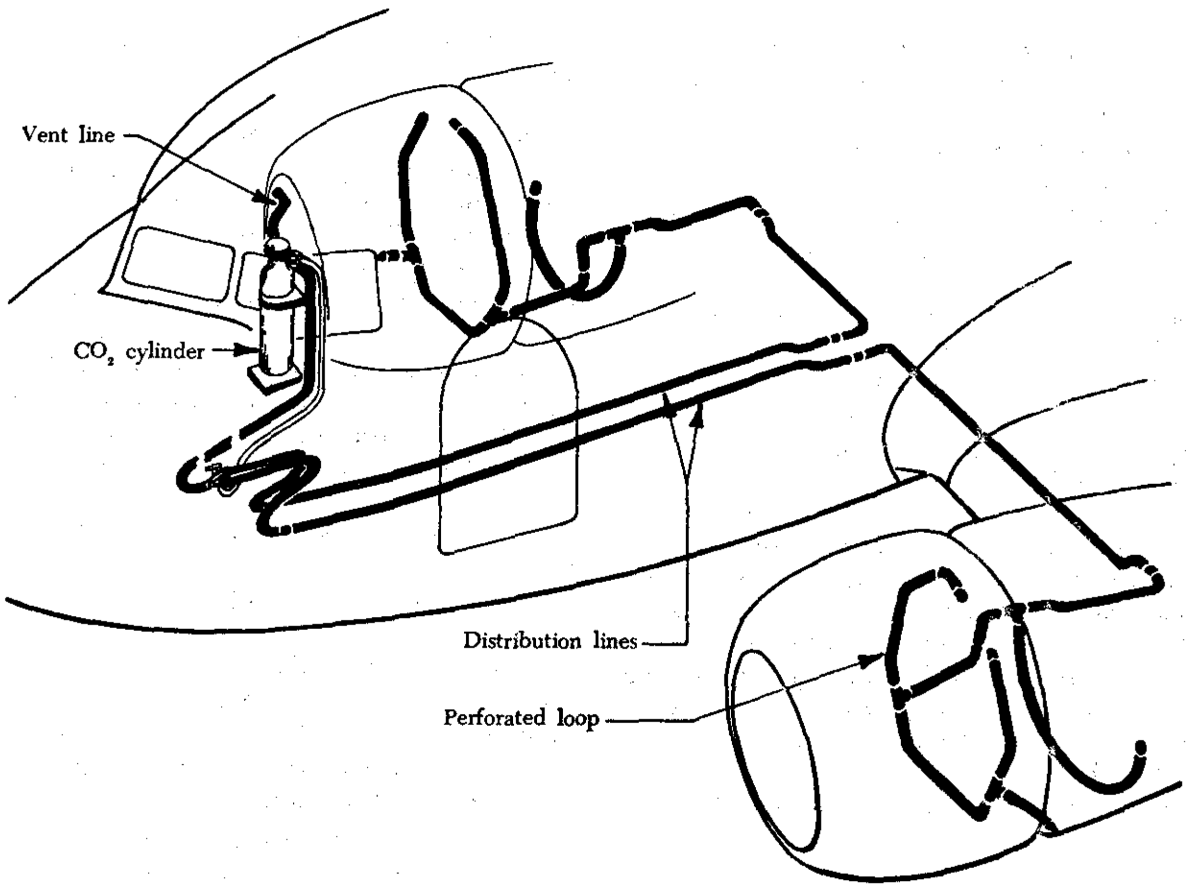

FIGURE 10–12. CO_2 fire extinguisher system on a twin-engine transport aircraft.

The various warning systems operate fire warning lights on the cockpit fire control panels and also energize a cockpit warning bell.

In one type of aircraft the CO_2 system consists of six cylinders, mounted three to a row in each side of the nose wheel well with flood valves installed on each CO_2 bottle. The flood valves of each row are connected with gas interconnect lines. The valves on the two aft bottles in each bank are designed to be opened mechanically by means of a cable connected to the discharge control handles on the main fire control panel in the cockpit. In case of discharge by mechanical means, the forward bottle flood valve in each bank is operated by the released CO_2 pressure from the two aft bottles through the interconnect lines. The flood valve on the forward bottle of each bank contains a solenoid. It is designed to be operated electrically by energizing the solenoid by depressing a button on the control panel. In case of a discharge by electrical means, the valves on the two aft bottles of each bank are operated by the released CO_2 pressure from the forward bottle through the interconnector lines.

Each bank of CO_2 bottles is equipped with a red thermosafety-discharge indicator disk set to rupture at or above a pressure of 2,650 p.s.i. Discharge overboard will occur at temperatures above 74° C. Each bank of bottles is also equipped with a yellow system-discharge indicator disk. Mounted adjacent to the red disk, the yellow disk indicates which bank of bottles has been emptied by a normal discharge.

This type of CO_2 fire protection system includes a fire warning system. It is a continuous-loop, low-impedance, automatic re-setting type for the engine and nacelle areas.

A single fire detector circuit is provided for each engine and nacelle area. Each complete circuit consists of a control unit, sensing elements, a test relay, a fire warning signal light, and a fire warning signal circuit relay. Associated equipment such as flexible connector assemblies, wire, grommets, mounting brackets, and mounting clamps are used in various quantities, depending upon individual installation requirements. On a four-engine aircraft, four warning light assemblies, one for each engine and nacelle area, give corresponding warning indications when an alarm is initiated by a respective engine fire warning circuit. Warning light assemblies in the CO_2 manual release handles are connected into all four engine fire detector circuits, along with a fire warning bell with its guarded cutoff switch and indicating light.

The insulated wire of the detector circuit runs from the control unit in the radio compartment, through the fuselage and wing, to the test relay. The wire is then routed through the nacelle and engine sections and back to the test relay, where it is joined to itself to form a loop.

The control units are normally located on a radio compartment rack. Each unit contains tubes or transistors, transformers, resistors, capacitors, and a potentiometer. It also contains an integrated circuit which introduces a time delay that desensitizes the warning system to short-duration transient signals that would otherwise cause momentary false alarms. When a fire or overheat condition exists in an engine or nacelle area, the resistance of the sensing loop decreases below a preset value determined by the setting of the control unit potentiometer which is in the bias circuit of the control unit detector and amplifier circuit. The output of this circuit is used to energize the fire warning bell and fire warning light.

TURBOJET FIRE PROTECTION SYSTEM

A fire protection system for a large multi-engine turbojet aircraft is described in detail in the following paragraphs. This system is typical of most turbojet transport aircraft and includes components and systems typically encountered on all such aircraft.

The fire protection system of most large turbine engine aircraft consists of two subsystems: (1) A fire detection system and (2) a fire extinguishing system. These two subsystems provide fire protection not only to the engine and nacelle areas but also to such areas as the baggage compartments and wheel wells.

Each turbine engine installed in a pod and pylon configuration contains an automatic heat-sensing fire detection circuit. This circuit consists of a heat-sensing unit, a control unit, a relay, and warning devices. The warning devices normally include a warning light in the cockpit for each circuit and a common alarm bell used with all such circuits.

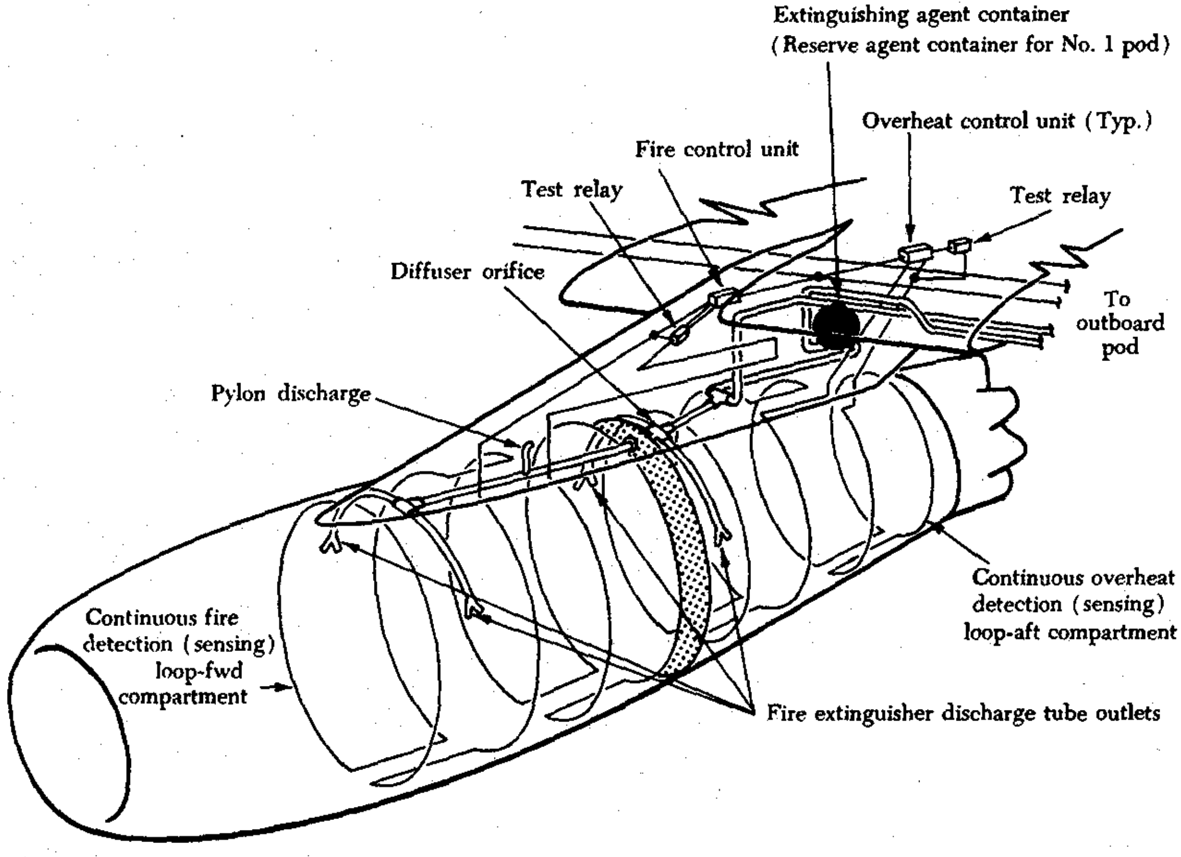

FIGURE 10–13. Typical pod and pylon fire protection installation.

The heat-sensing unit of each circuit is a continuous loop routed around the areas to be protected. These areas are the burner and tailpipe areas. Also included in most turbine engine aircraft are the compressor and accessory areas, which in some installations may be protected by a separate fire protection circuit. Figure 10–13 illustrates the typical routing of a continuous-loop fire detection circuit. A typical continuous loop is made up of sensing elements joined to each other by moistureproof connectors, which are attached to the aircraft structure. In most installations, the loop is supported by attachments or clamps every 10 to 12 in. of its length. Too great a distance between supports may permit vibration or chafing of the unsupported section and become a source of false alarms.

In a typical turbine engine fire detection system, a separate control unit is provided for each sensing circuit. The control unit contains an amplifier, usually a transistorized or magnetic amplifier, which produces an output when a predetermined input current flow is detected from the sensing loop. Each control unit also contains a test relay, which is used to simulate a fire or overheat condition to test the circuit. All the control units are mounted in a relay shield or junction box located in a radio compartment or in a special area of the cockpit.

The output of the control unit amplifier is used to energize a warning relay, often called a fire relay. Usually located near the control units, these fire relays, when energized, complete the circuit to appropriate warning devices.

The warning devices for engine and nacelle fires and overheat conditions are located in the cockpit. A fire warning light for each engine is usually located in a special fire switch handle on the instrument panel, light shield, or fire control panel. These fire switches are sometimes referred to as fire-pull T-handles. As illustrated in figure 10–14, the T-handle contains the fire detection warning light. In some models of this fire-pull switch, pulling the T-handle exposes a previously inaccessible extinguishing agent switch and also actuates microswitches which energize the emergency fuel shutoff valve and other pertinent shutoff valves.

TURBINE ENGINE FIRE EXTINGUISHING SYSTEM

The typical fire extinguishing portion of a complete fire protection system includes a cylinder or container of extinguishing agent for each engine and nacelle area. One type of installation provides for a container in each of four pylons on a multi-engine aircraft. This type of system uses an extinguishing agent container similar to the type shown in figure 10–15. This type of container is equipped with two discharge valves which are operated by electrically discharged cartridges. These two valves are the main and the reserve controls which release and route the agent to the pod and pylon in which the container is located or to the other engine on the same wing. This type of two-shot, crossfeed configuration permits the release of a second charge of fire extinguishing agent to the same engine if another fire breaks out, without providing two containers for each engine area.

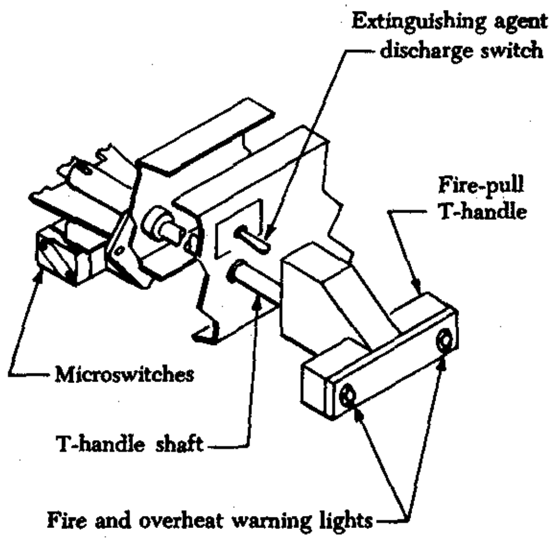

FIGURE 10–14. Fire-pull T-handle switch.

Another type of four-engine installation uses two independent fire extinguisher systems. The two engines on one side of the aircraft are equipped with two fire extinguisher containers, but they are located together in the inboard pylon (figure 10–16). A pressure gage, a discharge plug, and a safety discharge connection are provided for each container. The discharge plug is sealed with a breakable disk combined with an explosive charge which is electrically detonated to discharge the contents of the bottle. The safety discharge connection is capped at the inboard side of the strut with a red indicating disk. If the temperature rises beyond a predetermined safe value, the disk will rupture, dumping the agent overboard, and the discharge will be indicated in the cockpit.

The manifold connecting the two containers of the dual installation (figure 10–16) includes a double check valve and a tee-fitting from which tubing connects to the discharge indicator. This indicator is capped at the inboard side of the strut with a

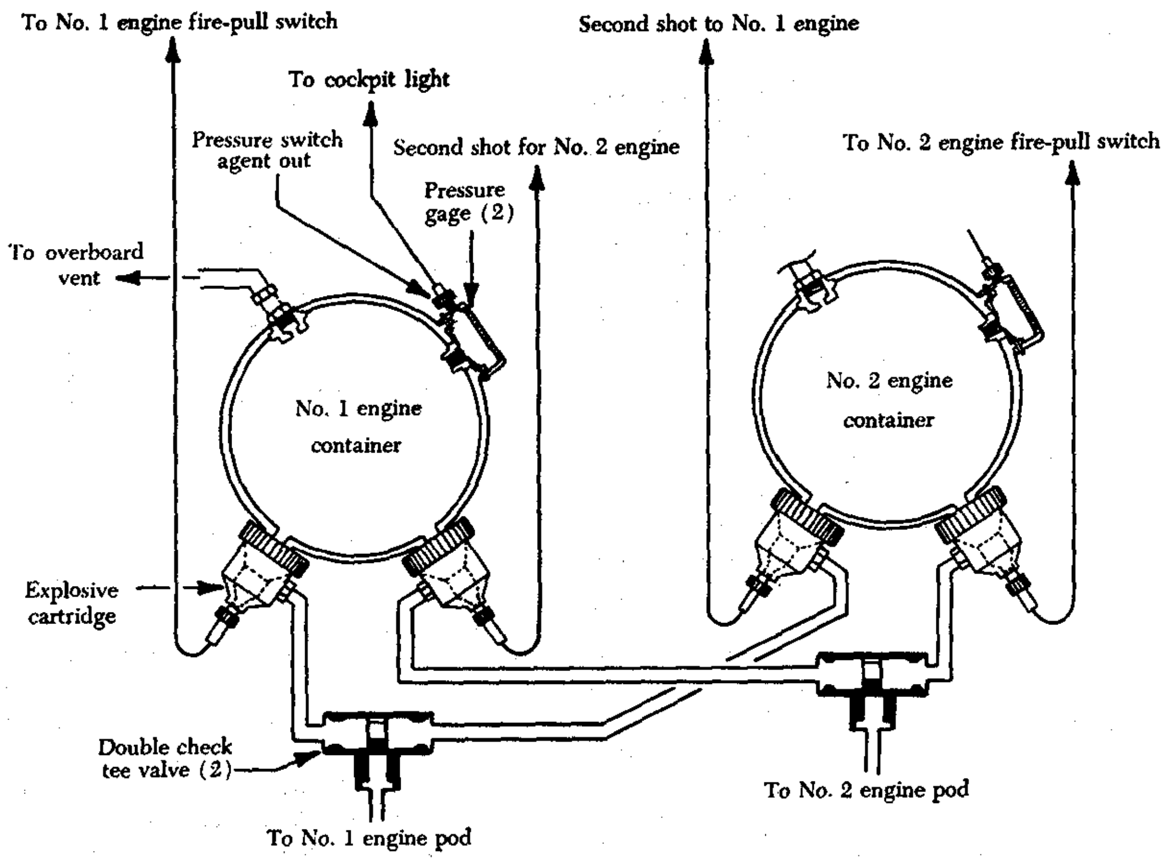

FIGURE 10–15. Fire extinguisher system for a multi-engine aircraft.

yellow disk, which is blown out when the manifold is pressurized from either container. The discharge line has two branches (figure 10–16), a short line to the inboard engine and a long one extending along the wing leading edge to the outboard engine. Both of the branches terminate in a tee-fitting near the forward engine mount.

Discharge tube configuration may vary with the type and size of turbine engine installations. In figure 10–17, a semicircular discharge tube with Y-outlet terminations encircles the top forward area of both the forward and aft engine compartments. Diffuser orifices are spaced along the diffuser tubes. A pylon discharge tube is incorporated in the inlet line to discharge the fire extinguishing agent into the pylon area.

Another type of fire extinguisher discharge configuration is shown in figure 10–18. The inlet discharge line terminates in a discharge nozzle, which is a tee-fitting near the forward engine mount. The tee-fitting contains diffuser holes which allow the fire extinguishing agent to be released along the top of the engine and travel downward along both sides of the engine.

When any section of the continuous-loop circuit is exposed to an overheat condition or fire, the detector warning lights in the cockpit illuminate and the fire warning bell sounds. The warning light may be located in the fire-pull T-handle, or in some installations the fire switch may incorporate the associated fire warning light for a particular engine under a translucent plastic cover, as shown in figure 10–19. In this system, a transfer switch is provided for the left and right fire extinguisher system. Each transfer switch has two positions: "TRANS" and "NORMAL." If a fire occurs in the No. 4 engine, the warning light in the No. 4 fire switch will illuminate; and with the transfer switch in the "NORMAL" position, the No. 4 fire switch is pulled and the No. 4 push button discharge switch located directly under the fire switch will be accessible. Activating the discharge switch will discharge a container of fire extinguishing agent into the No. 4 engine area.

If more than one shot of the agent is required, the transfer switch is placed in the "TRANS" position so that the second container can be discharged into the same engine.

An alarm bell control permits any one of the engine fire detection circuits to energize the

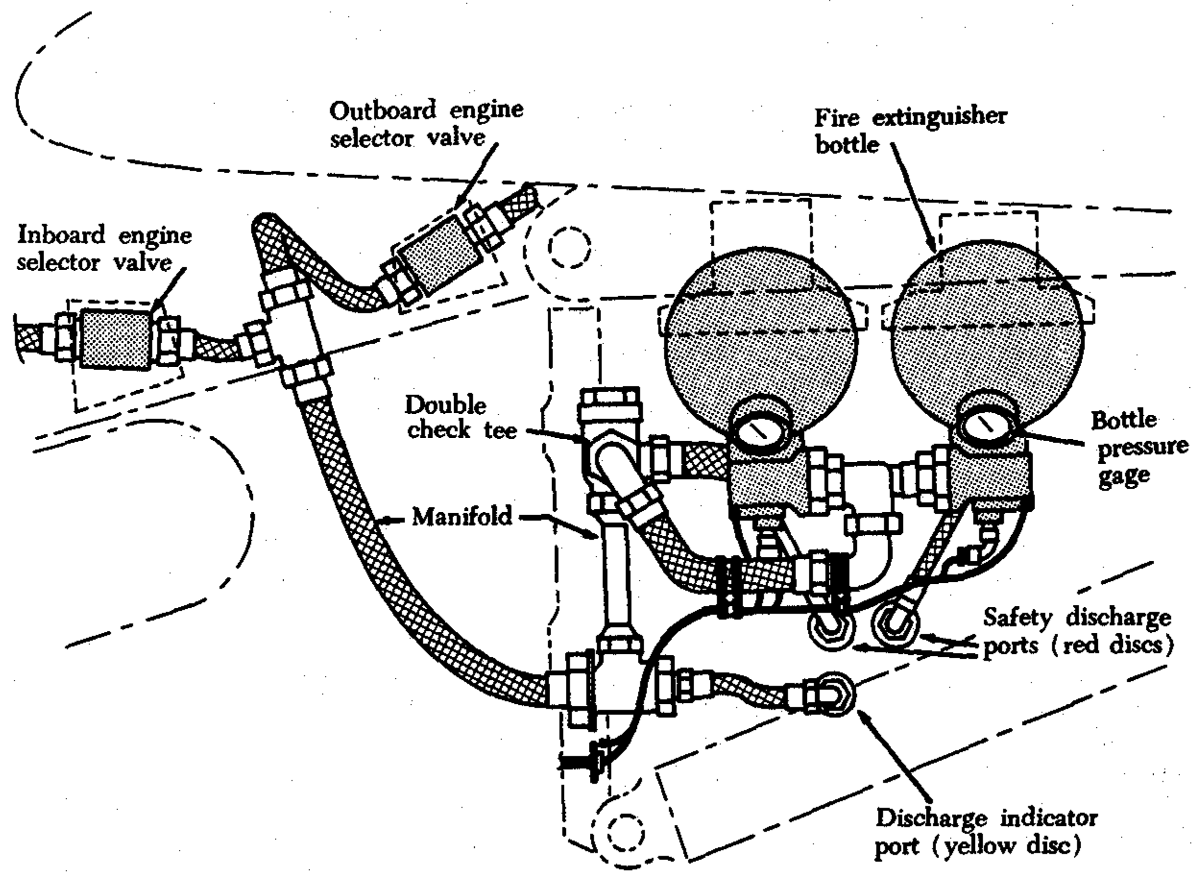

FIGURE 10–16. Dual container installation and fittings.

common alarm bell. After the alarm bell sounds, it can be silenced by activating the bell cutout switch (figure 10–19). The bell can still respond to a fire signal from any of the other circuits.

Most fire protection systems for turbine engine aircraft also include a test switch and circuitry which permit the entire detection system to be tested at one time. The test switch is located in the center of the panel in figure 10–19.

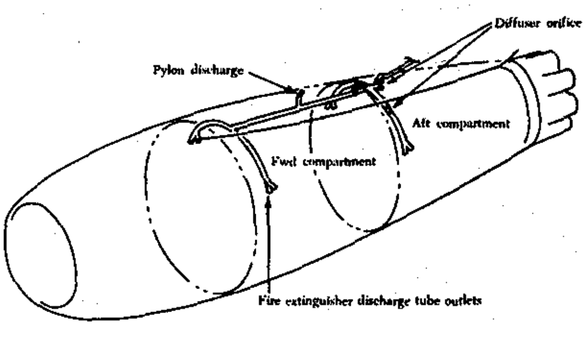

FIGURE 10–17. Fire extinguisher discharge tubes.

TURBINE ENGINE GROUND FIRE PROTECTION

The problem of ground fires has increased in seriousness with the increased size of turbine engine aircraft. For this reason, means are usually

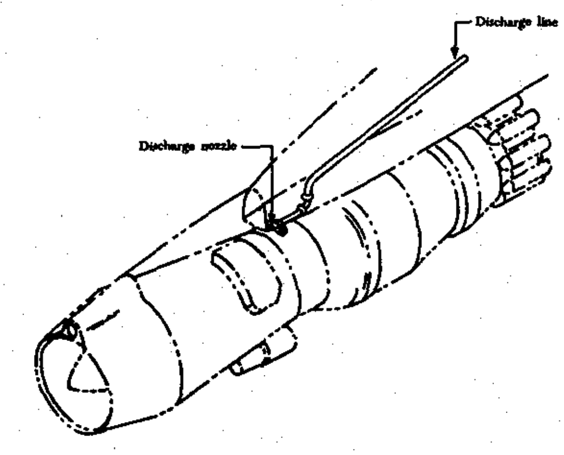

FIGURE 10–18. Fire extinguisher discharge nozzle location.

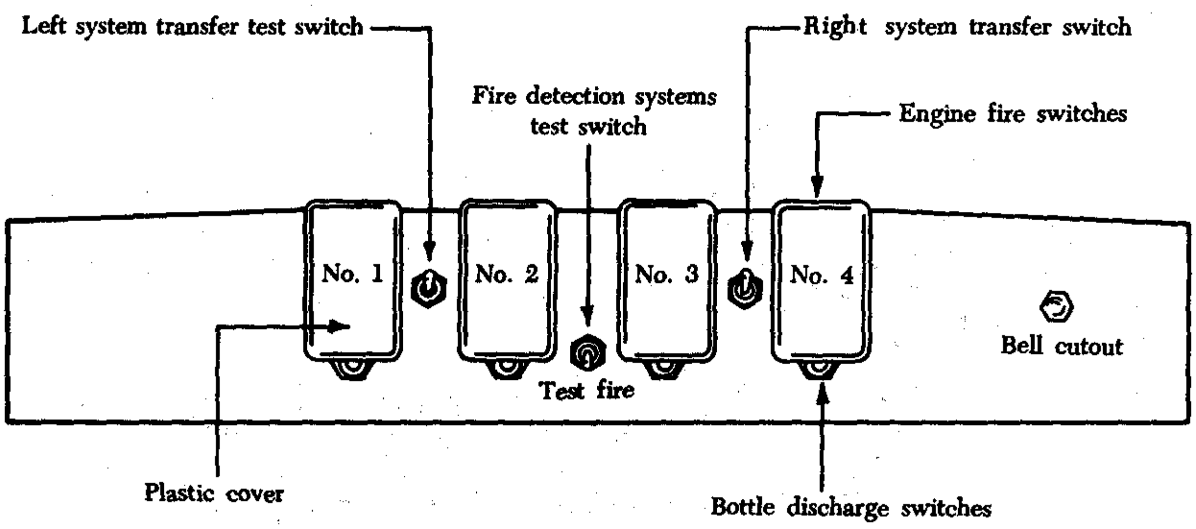

FIGURE 10–19. Fire detection system and fire switches.

provided for rapid access to the compressor, tailpipe, and/or burner compartments. Thus, many aircraft systems are equipped with spring-loaded access doors in the skin of the various compartments. Such doors are usually located in accessible areas, but not in a region where opening a door might spill burning liquids on the fire fighter.

Internal engine tailpipe fires that take place during engine shutdown or false starts can be blown out by motoring the engine with the starter. If the engine is running, it can be accelerated to a higher r.p.m. to achieve the same result. If such a fire persists, a fire extinguishing agent can be directed into the tailpipe. It should be remembered that excessive use of CO_2 or other agents which have a cooling effect can shrink the turbine housing onto the turbine and may damage the engine.

FIRE DETECTION SYSTEM MAINTENANCE PRACTICES

Fire detector sensing elements are located in many high-activity areas around aircraft engines. Their location, together with their small size, increases the chances of damage to the sensing elements during maintenance. The installation of the sensing elements inside the aircraft cowl panels provides some measure of protection not afforded elements attached directly to the engine. On the other hand, the removal and re-installation of cowl panels can easily cause abrasion or structural defects to the elements. A well-rounded inspection and maintenance program for all types of continuous-loop systems should include the following visual checks. These procedures are provided as examples and should not be used to replace approved local maintenance directives or the applicable manufacturer's instructions.

Sensing elements should be inspected for:

(1) Cracked or broken sections caused by crushing or squeezing between inspection plates, cowl panels, or engine components.
(2) Abrasion caused by rubbing of element on cowling, accessories, or structural members.
(3) Pieces of safety wire or other metal particles which may short the spot detector terminals.
(4) Condition of rubber grommets in mounting clamps, which may be softened from exposure to oils, or hardened from excessive heat.
(5) Dents and kinks in sensing element sections. Limits on the element diameter, acceptable dents or kinks, and degree of smoothness of tubing contour are specified by manufacturers. No attempt should be made to straighten any acceptable dent or kink, since stresses may be set up that could cause tubing failure. (See illustration of kinked tubing in figure 10–20.)
(6) Loose nuts or broken safety wire at the end of the sensing elements (figure 10–21). Loose nuts should be re-torqued to the value specified in the manufacturer's instructions. Some types of sensing element connections require the use of

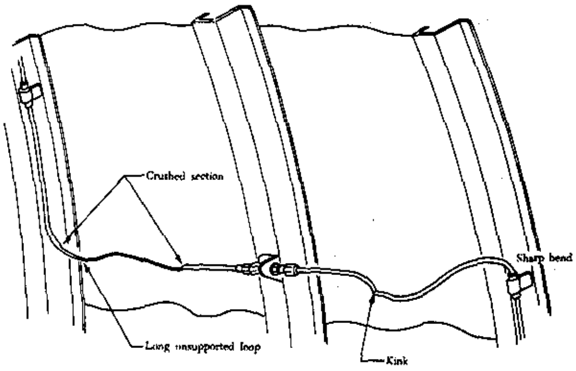

FIGURE 10–20. Sensing element defects.

copper crush gaskets. These gaskets should be replaced any time a connection is separated.

(7) Broken or frayed flexible leads, if used. The flexible lead is made up of many fine metal strands woven into a protective covering surrounding the inner insulated wire. Continuous bending of the cable or rough treatment can break these fine wires, especially those near the connectors. Broken strands can also protrude into the insulated gasket and short the center electrode.

(8) Proper sensing element routing and clamping (figure 10–22). Long unsupported sections may permit excessive vibration which can cause breakage. The distance between clamps on straight runs is usually about 8 to 10 in., and is specified by each manufacturer. At end connectors, the first support clamp is usually located about 4 to 6 in. from the end

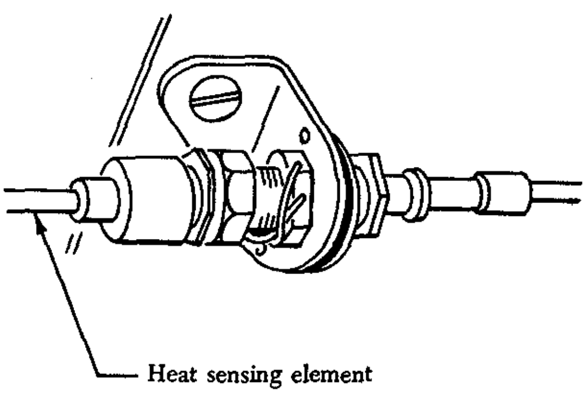

FIGURE 10–21. Connector joint fitting attached to structure.

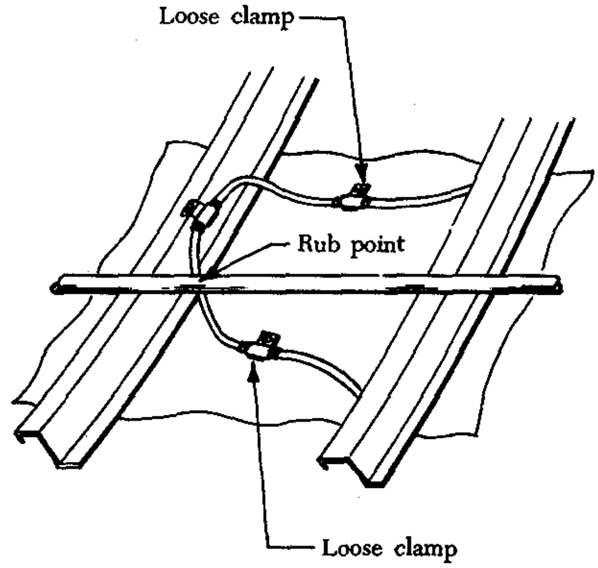

FIGURE 10–22. Rubbing interference.

connector fittings. In most cases, a straight run of 1 in. is maintained from all connectors before a bend is started, and an optimum bend radius of 3 in. is normally adhered to.

(9) Rubbing between a cowl brace and a sensing element (figure 10–22). This interference, in combination with loose rivets holding the clamps to skin, may cause wear and short the sensing element.

(10) Correct grommet installation. The grommets are installed on the sensing element to prevent the element from chafing on the clamp. The slit end of the grommet should face the outside of the nearest bend. Clamps and grommets (figure 10–23) should fit the element snugly.

(11) Thermocouple detector mounting brackets should be repaired or replaced when cracked, corroded, or damaged. When replacing a thermocouple detector, note which wire is connected to the identified plus terminal of the defective unit and connect the replacement in the same way.

(12) Test the fire detection system for proper operation by turning on the power supply and placing the fire detection test switch in the "TEST" position. The red warning light should flash on within the time period established for the system. On some aircraft an audible alarm will also sound.

In addition, the fire detection circuits are checked for specified resistance and for an open or grounded condition. Tests required after repair of replacement of units in a fire detection system or when the system is inoperative include: (1) Checking the polarity, ground, resistance and continuity of systems that use thermocouple detector units, and (2) resistance and continuity tests performed on systems with sensing elements or cable detector units. In all situations follow the recommended practices and procedures of the manufacturer of the type system with which you are working.

FIRE DETECTION SYSTEM TROUBLESHOOTING

The following troubleshooting procedures represent the most common difficulties encountered in engine fire detection systems.

(1) Intermittent alarms are most often caused by an intermittent short in the detector system wiring. Such shorts may be caused by a loose wire which occasionally touches a nearby terminal, a frayed wire brushing against a structure, or a sensing element rubbing long enough against a structural member to wear through the insulation. Intermittent faults can often best be located by moving wires to recreate the short.

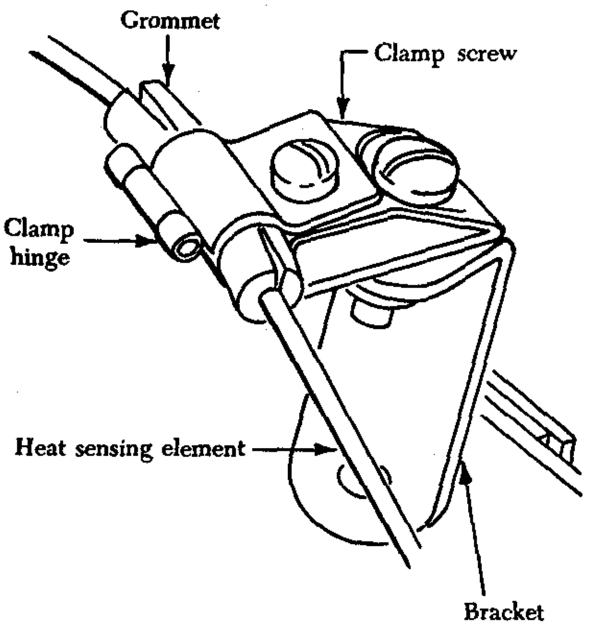

FIGURE 10-23. Typical fire detector loop clamp.

(2) Fire alarms and warning lights can occur when no engine fire or overheat condition exists. Such false alarms can most easily be located by disconnecting the engine sensing loop from the aircraft wiring. If the false alarm continues, a short must exist between the loop connections and the control unit. If, however, the false alarm ceases when the engine sensing loop is disconnected, the fault is in the disconnected sensing loop, which should be examined for areas which have been bent into contact with hot parts of the engine. If no bent element can be found, the shorted section can be located by isolating and disconnecting elements consecutively around the entire loop.

(3) Kinks and sharp bends in the sensing element can cause an internal wire to short intermittently to the outer tubing. The fault can be located by checking the sensing element with a megger while tapping the element in the suspected areas to produce the short.

(4) Moisture in the detection system seldom causes a false fire alarm. If, however, moisture does cause an alarm, the warning will persist until the contamination is removed or boils away and the resistance of the loop returns to its normal value.

(5) Failure to obtain an alarm signal when the test switch is actuated may be caused by a defective test switch or control unit, the lack of electrical power, inoperative indicator light, or an opening in the sensing element or connecting wiring. When the test switch fails to provide an alarm, the continuity of a two-wire sensing loop can be determined by opening the loop and measuring the resistance. In a single-wire, continuous-loop system, the center conductor should be grounded.

FIRE EXTINGUISHER SYSTEM MAINTENANCE PRACTICES

Regular maintenance of fire extinguisher systems typically includes such items as the inspection and servicing of fire extinguisher bottles (containers), removal and re-installation of cartridge and discharge valves, testing of discharge tubing for leakage, and electrical wiring continuity tests. The following paragraphs contain details of some of the most typical maintenance procedures, and are in-

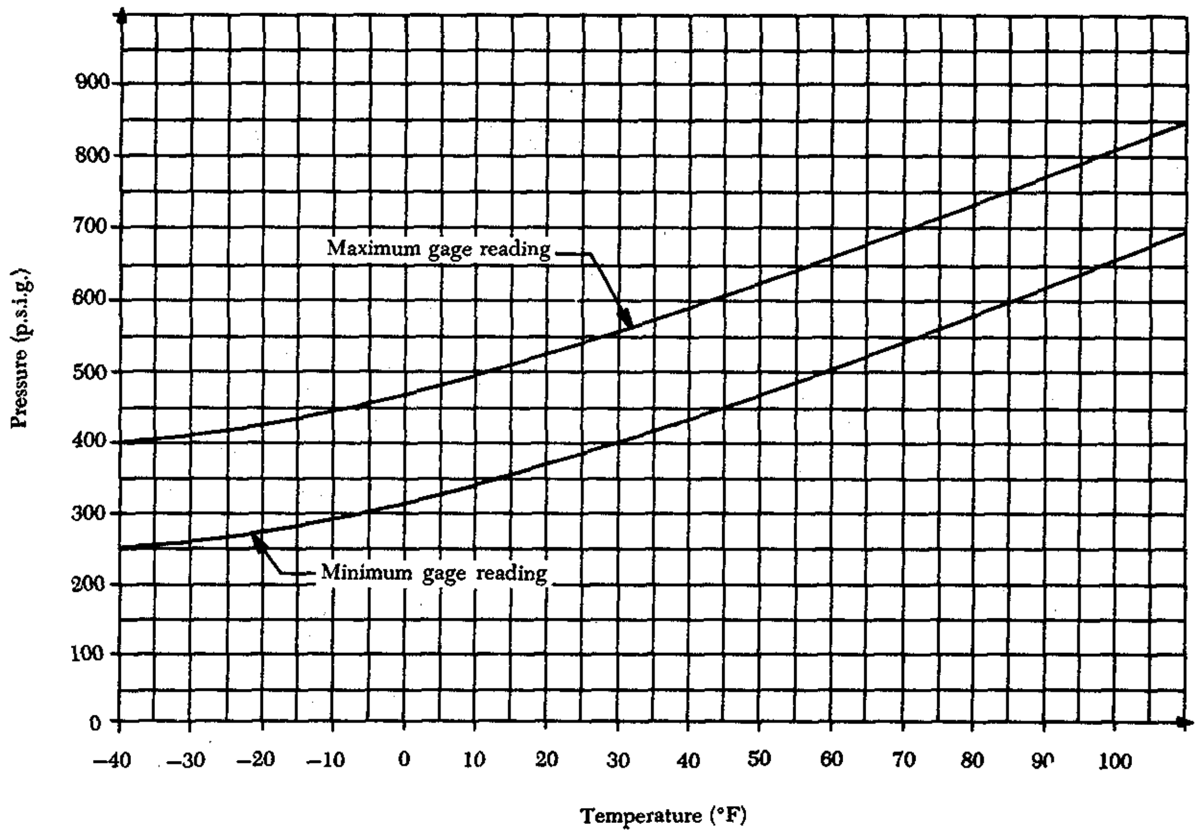

FIGURE 10-24. Fire extinguisher container pressure/temperature curve.

cluded to provide an understanding of the operations involved.

Fire extinguisher system maintenance procedures vary widely according to the design and construction of the particular unit being serviced. The detailed procedures outlined by the airframe or system manufacturer should always be followed when performing maintenance.

Container Pressure Check

A pressure check of fire extinguisher containers is made periodically to determine that the pressure is between the minimum and maximum limits prescribed by the manufacturer. Changes of pressure with ambient pressure must also fall within prescribed limits. The graph shown in figure 10-24 is typical of the pressure/temperature curve graphs that provide maximum and minimum gage readings. If the pressure does not fall within the graph limits, the extinguisher container should be replaced.

Freon Discharge Cartridges

The service life of fire extinguisher discharge cartridges is calculated from the manufacturer's date stamp, which is usually placed on the face of the cartridge. The manufacturer's service life is usually recommended in terms of hours below a predetermined temperature limit. Many cartridges are available with a service life of approximately 5,000 hours. To determine the unexpired service life of a discharge cartridge, it is necessary to remove the electrical leads and discharge hose from the plug body, which can then be removed from the extinguisher container.

Care must be taken in the replacement of cartridge and discharge valves. Most new extinguisher containers are supplied with their cartridge and discharge valve disassembled. Before installation on the aircraft, the cartridge must be properly assembled into the discharge valve and the valve connected to the container, usually by means of a swivel nut that tightens against a packing ring gasket.

If a cartridge is removed from a discharge valve for any reason, it should not be used in another discharge valve assembly, since the distance the contact point protrudes may vary with each unit. Thus, continuity might not exist if a used plug which had been indented with a long contact point were installed in a discharge valve with a shorter contact point.

When actually performing maintenance, always refer to the applicable maintenance manuals and other related publications pertaining to a particular aircraft.

Freon Containers

Bromochloromethane and freon extinguishing agents are stored in steel spherical containers. There are four sizes in common use today ranging from 224 cu. in. (small) to 945 cu. in. (large). The large containers weigh about 33 lbs. The small spheres have two openings, one for the bonnet assembly (sometimes called an operating head), and the other for the fusible safety plug (figure 10–25). The larger containers are usually equipped with two firing bonnets and a two-way check valve as shown in figure 10–26.

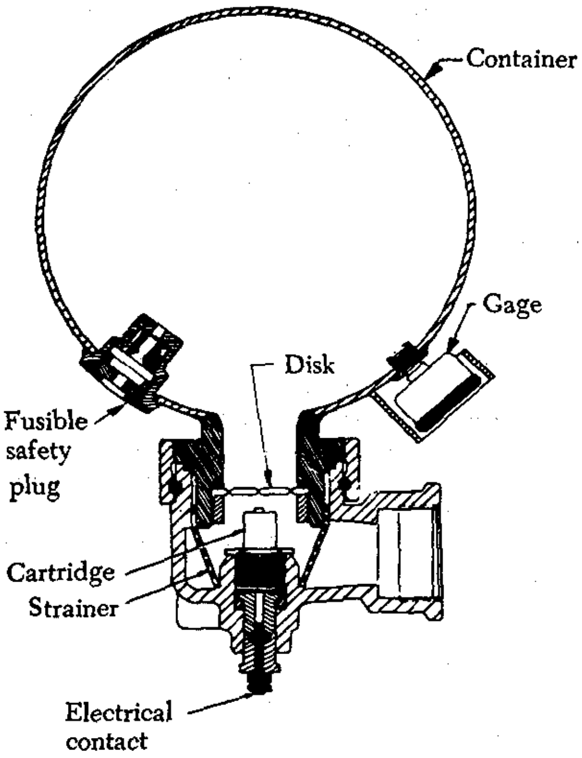

FIGURE 10–25. Single bonnet sphere assembly.

The containers are charged with dry nitrogen in addition to a specified weight of the extinguishing agent. The nitrogen charge provides sufficient pressure for complete discharge of the agent. The bonnet assembly contains an electrically ignited power cartridge which breaks the disk, allowing the extinguishing agent to be forced out of the sphere by the nitrogen charge.

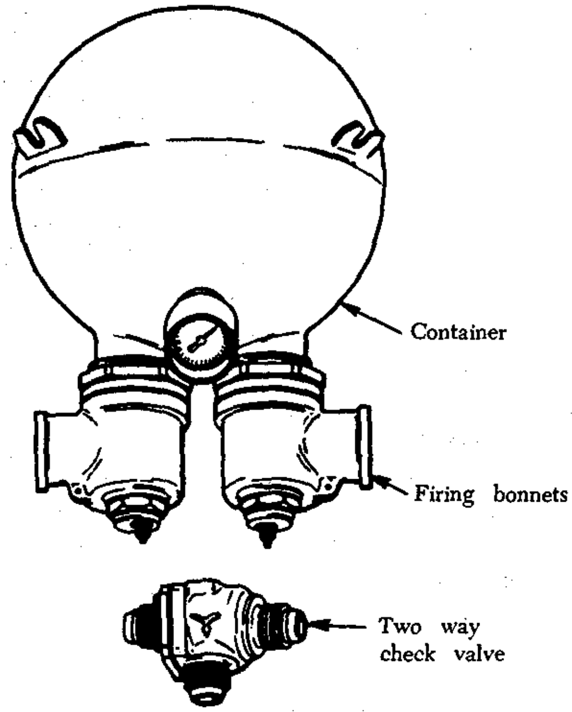

FIGURE 10–26. Typical double bonnet extinguisher assembly.

A single bonnet sphere assembly is illustrated in figure 10–25. The function of the parts shown, other than those described in the preceding paragraph, are as follows: (1) The strainer prevents pieces of the broken disk from entering the system, (2) the fusible safety plug melts and releases the liquid when the temperature is between 208° and 220° F., and (3) the gage shows the pressure in the container. In this type of design, there is no need for siphon tubes.

In some installations the safety plug is connected to a discharge indicator mounted in the fuselage skin, while others simply discharge the fluid into the fire extinguisher container storage compartment.

The gage on the container should be checked for an indication of the specified pressure as given in the applicable aircraft maintenance manual. In addition make certain that the indicator glass is unbroken and that the bottle is securely mounted.

Some types of extinguishing agents rapidly corrode aluminum alloy and other metals, especially under humid conditions. When a system that uses a corrosive agent has been discharged, the system must be purged thoroughly with clean, dry, compressed air as soon as possible.

Almost all types of fire extinguisher containers require re-weighing at frequent intervals to determine the state of charge. In addition to the weight check, the containers must be hydrostatically tested, usually at 5-year intervals.

The circuit wiring of all electrically discharged containers should be inspected visually for condition. The continuity of the entire circuit should be checked following the procedures in the applicable maintenance manual. In general this consists of checking the wiring and the cartridge, by using a resistor in the test circuit that limits the circuit current to less than 35 milliamperes to prevent detonating the cartridge.

Carbon Dioxide Cylinders

These cylinders come in various sizes, are made of stainless steel, and are wrapped with steel wire to make them shatterproof. The normal storage pressure of the gas ranges from 700 to 1,000 p.s.i. However, the state of the cylinder charge is determined by the weight of the CO_2. In the container, about two-thirds to three-fourths of the CO_2 is liquefied. When the CO_2 is released, it expands about 500 times as it converts to gas.

The cylinder does not have to be protected against cold weather, for the freezing point of carbon dioxide is minus 110° F. However, it can discharge prematurely in hot climates. To prevent this, manufacturers put in a charge of dry nitrogen, at about 200 p.s.i., before they fill the cylinder with carbon dioxide. When treated in this manner, most CO_2 cylinders are protected against premature discharge up to 160° F. With a temperature increase, the pressure of the nitrogen does not rise as much as that of the CO_2 because of its stability with regard to temperature changes. The nitrogen also provides additional pressure during normal release of the CO_2 at low temperature during cold weather.

Carbon dioxide cylinders are equipped internally with one of three types of siphon tubes, as shown in figures 10–27 and 10–28. Aircraft fire extinguishers have either the straight rigid or the short flexible siphon tube installed. The tube is used to make certain that the CO_2 is transmitted to the discharge nozzle in the liquid state.

Cylinders containing either the straight rigid or short flexible types of siphoning tubes should be mounted as shown in figure 10–28. Notice that the straight rigid siphon tube is allowed a 60° tolerance, while the tolerance for the short flexible tube is only 30°.

CO_2 cylinders are equipped with metal safety disks designed to rupture at 2,200 to 2,800 p.s.i. This disk is attached to the cylinder release valve body by a threaded plug. A line leads from the fitting to a discharge indicator installed in the fuselage skin. Rupture of the red disk means that

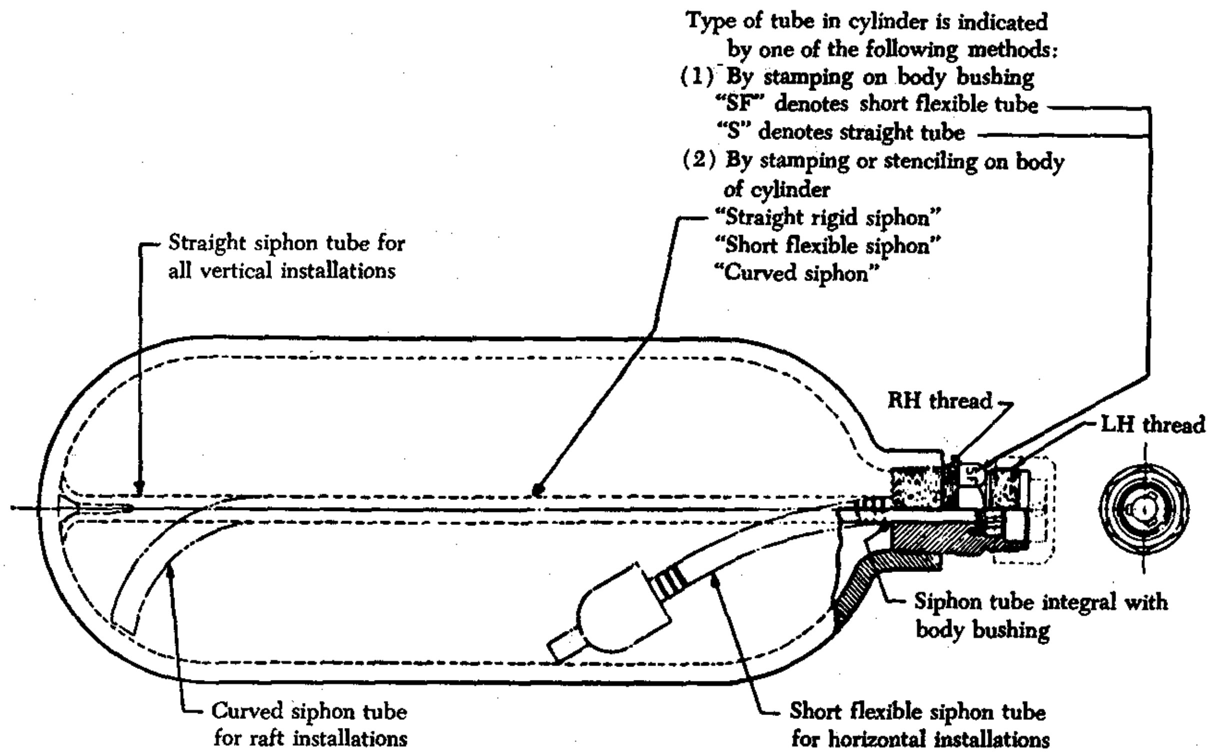

FIGURE 10–27. Typical CO_2 cylinder construction.

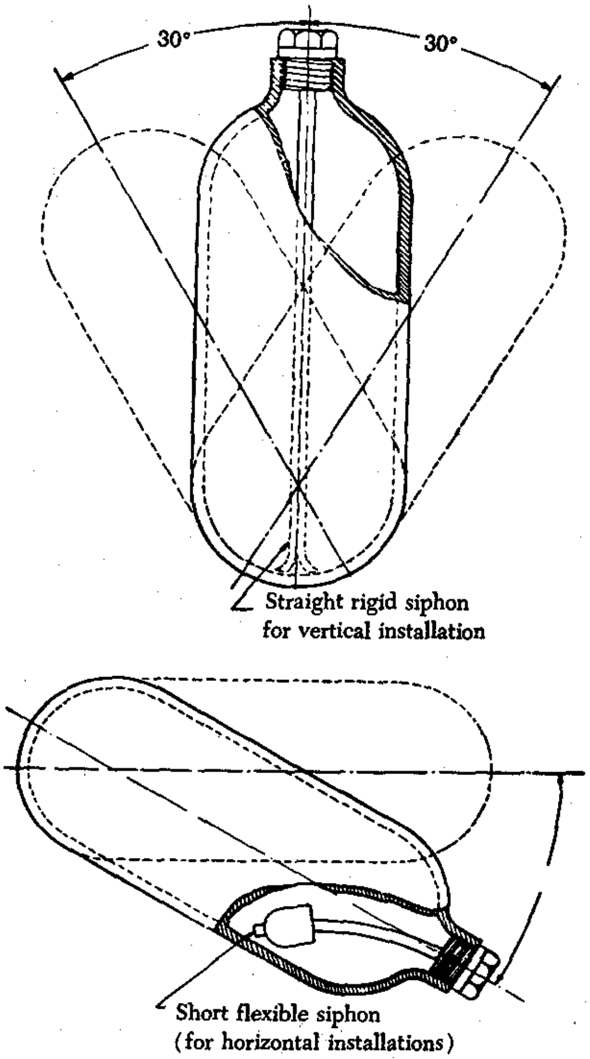

FIGURE 10–28. Mounting positions of CO_2 cylinders.

the container safety plug has ruptured because of an overheat condition. A yellow disk is also installed in the fuselage skin. Rupture of this disk indicates that the system has been discharged normally.

FIRE PREVENTION AND PROTECTION

Leaking fuel and hydraulic, de-icing, or lubricating fluids, can be sources of fire in an aircraft. This condition should be noted, and corrective action taken, when inspecting aircraft systems. Minute pressure leaks of these fluids are particularly dangerous for they quickly produce an explosive atmospheric condition.

Carefully inspect fuel tank installations for signs of external leaks. With integral fuel tanks the external evidence may occur at some distance from where the fuel is actually escaping.

Many hydraulic fluids are flammable and should not be permitted to accumulate in the structure. Sound-proofing and lagging materials may become highly flammable if soaked with oil of any kind.

Any leakage or spillage of flammable fluid in the vicinity of combustion heaters is a serious fire risk, particularly if any vapor is drawn into the heater and passes over the hot combustion chamber.

Oxygen system equipment must be kept absolutely free from traces of oil or grease, since these substances will spontaneously ignite in contact with oxygen under pressure. Oxygen servicing cylinders should be clearly marked so that they cannot be mistaken for cylinders containing air or nitrogen, as explosions have resulted from this error during maintenance operations.

Fire prevention is much more rewarding than fire extinguishing.

COCKPIT AND CABIN INTERIORS

All wool, cotton, and synthetic fabrics used in interior trim are treated to render them flame resistant. Tests conducted have shown foam and sponge rubber to be highly flammable. However, if they are covered with a flame-resistant fabric which will not support combustion, there is little danger from fire as a result of ignition produced by accidental contact with a lighted cigarette or burning paper.

Fire protection for the aircraft interior is usually provided by hand-held extinguishers. Four types of fire extinguishers are available for extinguishing interior fires: (1) water, (2) carbon dioxide, and (3) dry chemical, and (4) halogenated hydrocarbons.

Extinguisher Types

(1) Water extinguishers are for use primarily on nonelectrical fires such as smoldering fabric, cigarettes, or trash containers. Water extinguishers should not be used on electrical fires because of the danger of electrocution. Turning the handle of a water extinguisher clockwise punctures the seal of a CO_2 cartridge which pressurizes the container. The water spray from the nozzle is controlled by a trigger on top of the handle.

(2) Carbon dioxide fire extinguishers are provided to extinguish electrical fires. A long, hinged tube with a non-metallic megaphone-shaped nozzle permits discharge of the CO_2 gas close to the fire source to smother the fire. A trigger type release is normally lockwired and the lockwire can be broken by a pull on the trigger.

(3) A dry chemical fire extinguisher can be used to extinguish any type of fire. However, the

dry chemical fire extinguisher should not be used in the cockpit due to possible interference with visibility and the collection of nonconductive powder on electrical contacts of surrounding equipment. The extinguisher is equipped with a fixed nozzle which is directed toward the fire source to smother the fire. The trigger is also lockwired but can be broken by a sharp squeeze of the trigger.

(4) The development of halogenated hydrocarbons (freons) as fire extinguishing agents with low toxicity for airborne fire extinguishing protection systems logically directed attention to its use in hand type fire extinguishers.

Bromotrifluoromethane (Halon 1301) having a rating of 6 on the toxicity scale is the logical successor to CO_2 as a hand type fire extinguisher agent. It is effective on fires in lower concentrations. Halon 1301 can extinguish a fire with a concentration of 2% by volume. This compares with about 40% by volume concentration required for CO_2 to extinguish the same fire.

This quality allows Halon 1301 to be used in occupied personnel compartments without depriving people of the oxygen they require. Another advantage is that no residue or deposit remains after use. Halogen 1301 is the ideal agent to use in airborne hand held fire extinguishers because: (1) its low concentration is very effective, (2) it may be used in occupied personnel compartments, (3) it is effective on all 3 type fires, and (4) no residue remaining after its use.

Extinguishers Unsuitable as Cabin or Cockpit Equipment

The common aerosol can type extinguishers are definitely not acceptable as airborne hand type extinguishers. In one instance, an aerosol type foam extinguisher located in the pilot's seat back pocket exploded and tore the upholstery from the seat. The interior of the aircraft was damaged by the foam. This occurred when the aircraft was on the ground and the outside air temperature was 90° F. In addition to the danger from explosion, the size is inadequate to combat even the smallest fire.

A dry chemical extinguisher was mounted near a heater vent on the floor. For an unknown reason, the position of the unit was reversed. This placed the extinguisher directly in front of the heater vent. During flight, with the heater in operation, the extinguisher became overheated and exploded filling the compartment with dry chemical powder. The proximity of heater vents should be considered when selecting a location for a hand fire extinguisher.

Additional information relative to airborne hand fire extinguishers may be obtained from the local FAA District Office and from the National Fire Protection Association, 470 Atlantic Ave., Boston, MA 02210.

SMOKE DETECTION SYSTEMS

A smoke detection system monitors the cargo and baggage compartments for the presence of smoke, which is indicative of a fire condition. Smoke detection instruments, which collect air for sampling, are mounted in the compartments in strategic locations. A smoke detection system is used where the type of fire anticipated is expected to generate a substantial amount of smoke before temperature changes are sufficient to actuate a heat detection system.

Smoke detection instruments are classified by method of detection as follows: Type I – Measurement of carbon monoxide gas (CO detectors), Type II – Measurement of light transmissibility in air (photoelectric devices), and Type III – Visual detection of the presence of smoke by directly viewing air samples (visual devices).

To be reliable, smoke detectors must be maintained so that smoke in a compartment will be indicated as soon as it begins to accumulate. Smoke detector louvers, vents, and ducts must not be obstructed.

Carbon Monoxide Detectors

The CO detectors, which detect concentrations of carbon monoxide gas, are rarely used to monitor cargo and baggage compartments. However, they have gained widespread use in conducting tests for the presence of carbon monoxide gas in aircraft cabins and cockpits.

Carbon monoxide is a colorless, odorless, tasteless, non-irritating gas. It is the byproduct of incomplete combustion, and is found in varying degrees in all smoke and fumes from burning carbonaceous substances. Exceedingly small amounts of the gas are dangerous. A concentration of .02% (2 parts in 10,000) may produce headache, mental dullness, and physical loginess within a few hours.

There are several types of portable testers (sniffers) in use. One type has a replaceable indicator tube which contains a yellow silica gel, impregnated with a complex silico-molybdate compound and is catalyzed using palladium sulfate.

In use, a sample of air is drawn through the detector tube. When the air sample contains carbon monoxide, the yellow silica gel turns to a shade of green. The intensity of the green color is proportional to the concentration of carbon monoxide in the air sample at the time and location of the tests.

Another type indicator may be worn as a badge or installed on the instrument panel or cockpit wall. It is a button using a tablet which changes from a normal tan color to progressively darker shades of gray to black. The transition time required is relative to the concentration of CO. At a concentration of 50 ppm CO (0.005%), the indication will be apparent within 15 to 30 minutes. A concentration of 100 ppm CO (0.01%) will change color of the tablet from tan to gray in 2–5 minutes, from tan to dark gray in 15 to 20 minutes.

Photoelectric Smoke Detectors

This type of detector consists of a photoelectric cell, a beacon lamp, a test lamp, and a light trap, all mounted on a labyrinth. An accumulation of 10% smoke in the air causes the photoelectric cell to conduct electric current. Figure 10–29 shows the details of the smoke detector, and indicates how the smoke particles refract the light to the photoelectric cell. When activated by smoke, the detector supplies a signal to the smoke detector amplifier. The amplifier signal activates a warning light and bell.

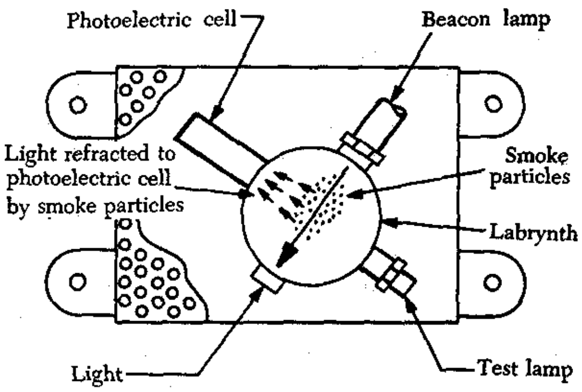

FIGURE 10–29. Photoelectric smoke detector.

A test switch (figure 10–30) permits checking the operation of the smoke detector. Closing the switch connects 28 v. d.c. to the test relay. When the test relay energizes, voltage is applied through the beacon lamp and test lamp in series to ground. A fire indication will be observed only if the beacon and test lamp, the photoelectric cell, the smoke detector amplifier, and associated circuits are operable.

A functional check of the detector should be made after installation, and at frequent intervals thereafter.

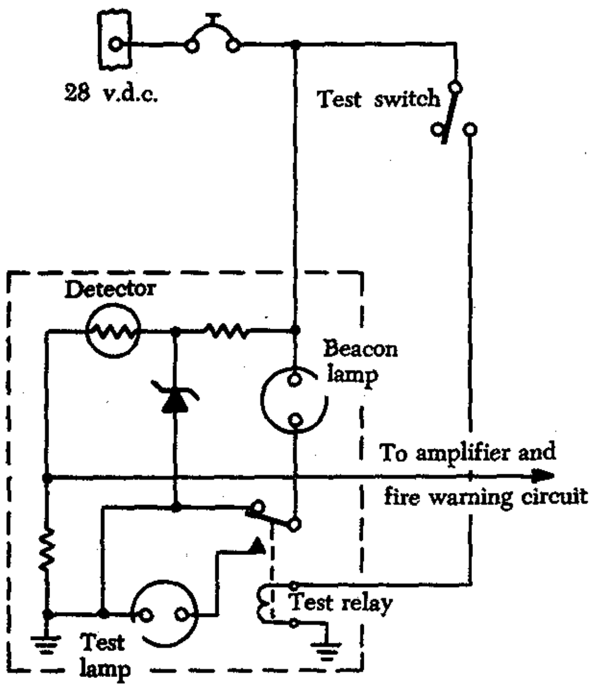

FIGURE 10–30. Smoke detector test circuit.

Visual Smoke Detectors

On a few aircraft visual smoke detectors provide the only means of smoke detection. Indication is provided by drawing smoke through a line into the indicator, using either a suitable suction device or cabin pressurization.

When smoke is present a lamp within the indicator is illuminated automatically by the smoke detector. The light is scattered so that the smoke is rendered visible in the appropriate window of the indicator. If no smoke is present the lamp will not be illuminated. A switch is provided to illuminate the lamp for test purposes. A device is also provided in the indicator to show that the necessary airflow is passing through the indicator.

The efficiency of any detection system depends on the positioning and serviceability of all the components of the system. The foregoing information is intended to provide familiarization with the various systems. For details of a particular installation, refer to the relevant manuals for the aircraft concerned.

The maximum allowable concentration, under Federal Law, for continuing exposure is 50 ppm (parts per million) which is equal to 0.005% of carbon monoxide. (See figure 10–31.)

The maximum allowable concentration under Federal Law for continuing exposure is 50 ppm (parts per million) which is equal to 0.005% of carbon monoxide.

Parts Per Million	Percentage	Reaction
50	0.005%	Maximum allowable concentration under Federal Law.
100	0.01 %	Tiredness, mild dizziness.
200	0.02 %	Headaches, tiredness, dizziness, nausea after 2 or 3 hours.
800	0.08 %	Unconsciousness in 1 hour and death in 2 to 3 hours.
2,000	0.20 %	Death after 1 hour.
3,000	0.30 %	Death within 30 minutes.
10,000	1.00 %	Instantaneous **death.**

FIGURE 10–31. Human reactions to carbon monoxide poisoning.